THE REFINING VALUE OF ETHANOL IN PADD 2

AS

GASOLINE BLENDSTOCK AND ETHERIFICATION FEEDSTOCK

Prepared by

Math*Pro Inc.*
Dave Hirshfeld
Jeff Kolb

Under Subcontract to

Information Resources, Inc.

for

The National Renewable Energy Laboratory

Under Contract No. ACG-5-15356-01

February 14, 1996

The Refining Value of Ethanol in PADD 2

as Gasoline Blendstock and Etherification Feedstock

This report describes an analysis of ethanol's long-term refining value in PADD 2 as a gasoline blendstock and an etherification feedstock. The work described in this report was carried out as part of Task 2 of NREL Subcontract No. ACG-5-15356-01 (21 September 1995).

This work extends prior work performed for NREL to analyze ethanol's value for the entire U.S. petroleum refining sector, as described in two previous reports. The first of the two reports, *The Refining Value of Ethanol as Gasoline Blendstock and Etherification Feedstock* (18 July 1995), was prepared under Subcontract No. AAW-4-14125-01. The second report, *Effects of the 1 psi Waiver on the Refining Value of Ethanol as Gasoline Blendstock and Etherification Feedstock* (14 November 1995), was prepared under Task 1 of this subcontract.

The prior work: (1) explored the technical determinants of ethanol's refining value as a gasoline blendstock and as an etherification feedstock; (2) developed aggregate demand functions for fuel-grade ethanol in the entire U.S. refining sector, for the year 2010; and (3) explored the effects on aggregate demand curves of the current 1 psi RVP waiver for ethanol-blended gasoline. The estimated demand functions corresponded to various crude oil and natural gas prices projected for 2010 in DoE's *1995 Annual Energy Outlook* and reflected assumptions regarding future refining technology, refining economics, and public policies bearing on gasoline quality and composition.

1.0 Objective of this Study

This analysis develops aggregate demand functions for fuel-grade ethanol for the year 2010 expressly for refineries in PADD 2:

- for three forecast levels of crude oil and natural gas prices reported by the Energy Information Administration in the *1995 Annual Energy Outlook* (AEO) -- the low, reference, and high oil price cases for the year 2010; and

- under the assumption that no public policies, including the 1 psi RVP waiver, would be in place to promote the use of ethanol by the refining sector.

In general, the work described here embodies the same methodology and assumptions as did the 18 July report and the reader interested in these matters should refer to that report. Further, the 14 November report indicates how maintaining the current 1 psi waiver likely would affect the refining values for ethanol estimated in this report.

The results of this PADD 2 analysis are consistent with those of previous studies of the entire U.S refining sector. In particular, the effects of changes in various assumptions on the "demand curves" for ethanol estimated in the previous studies (e.g., refining capacity optimized for ethanol availability and retention of the 1 psi RVP waiver) would apply to the PADD 2 "demand curves" estimated in this study.

2.0 Overview of PADD 2

PADD 2 consists of fifteen states in the Midwest, as shown in Exhibit 1. Gasoline consumption in PADD 2 is about 2.3 million bbl/d, or about 30% of total U.S. gasoline consumption. Of this, about 9% is reformulated gasoline (RFG) (EIA-PSM, Dec. 1995).[1]

There are 33 operating refineries in PADD 2, with an aggregate crude distillation capacity of about 3.6 million bbl/d, about 22% of total U.S. capacity. Exhibit 2 shows current process capacities for each refinery in PADD 2, along with aggregate capacity. Refineries in four states -- Illinois, Indiana, Ohio, and Oklahoma -- account for about 70% of PADD 2's distillation capacity and gasoline-making capacity.

Exhibit 3 shows the volume, quality, and source of the crude oils processed by PADD 2 refineries in 1994. Domestic crude oil accounted for about 61% of crude oil use. Domestic crude oil processed by PADD 2 refineries tends to be lighter and lower in sulfur content than the imported crude oils. Canada accounted for about 56% of crude imports; Venezuela, the next largest source, accounted for 11%.

Gasoline production by PADD 2 refineries is about 1.8 million bbl/d, about 0.45 million bbl/d less than gasoline consumption in PADD 2. The shortfall is made up by shipments of gasoline from PADDs 1 and 3, which contribute about 25% and 75%, repectively, of net gasoline shipments into PADD 2 (EIA-PSA, 1994). About 12% of gasoline output by PADD 2 refineries is RFG. Only minor volumes of RFG are shipped to PADD 2 from other PADDs.

As shown in Exhibit 4, the bulk (about 98%) of U.S. production capacity for corn-based ethanol, is in PADD 2. There are 34 operating ethanol plants in PADD 2, with several more scheduled to come on line either in late 1995 or 1996. The aggregate production capacity of these plants is about 106,000 bbl/d.[2] Many of the ethanol plants in PADD 2 are small -- thirteen

---

[1] In PADD 2, RFG is required only in the Milwaukee-Chicago metropolitan area. This market is distant from other PADDs. It can be fully supplied by refineries located in Illinois and Indiana -- it requires roughly 40% of the gasoline make of such refineries.

[2] Domestic consumption of fuel-grade ethanol in 1994 averaged about 68,000 bbl/d (of which only about 1,000 bbl/d were imported) (1994 Highway Statistics). Domestic production averaged about 83,500 bbl/d in 1994 (EIA-PSM, Dec. 1995). In a recent multi-client study, IRI projected that domestic use of fuel-grade ethanol would increase to about 89,000 bbl/d in 1995 and to about 100,000 bbl/d by 2000.

have production capacity of less than 1,000 bbls/d. Archer Daniels Midland (ADM) accounts for about 45% of the production capacity in PADD 2 with its four large operating plants. Several ethanol plants opened recently in Nebraska and Minnesota, taking advantage of large production subsidies offered by those states. The South Point plant and ADM's North Dakota plant were closed in 1995 due to current poor operating margins. About 65% of the 82,000 bbl/d of fuel-grade ethanol produced in PADD 2 in 1994 was used in PADD 2.[3] Most of the remainder was used in oxygenated gasoline required during the winter in various regions of the country, primarily the West, or was exported to Brazil.[4]

Little ether production capacity exists in PADD 2, and all of it is refinery-based. According to DOE data, two MTBE plants and two ETBE plants were operating as of January 1995 with aggregate production capacity of 4,200 and 3,200 bbl/d, respectively. Two other MTBE plants, idle at that time, have an aggregate production capacity of about 4,700 bbl/d.

RFG is required in the Milwaukee-Chicago area, which is a severe ozone non-attainment area. This area accounts for about 9% of gasoline consumption in PADD 2. Numerous other metropolitan areas in PADD 2 currently are in non-attainment with the ozone standard, but are not required to be part of the RFG program.

The RFG requirement in PADD 2 may increase in the future. For example, EPA is beginning a review process to determine whether to revise the existing 1-hour ozone standard of 0.12 ppm. Certain groups, such as the American Heart Association, argue that an 8-hour standard of 0.08 ppm would be more protective of human health. An 8-hour standard of 0.08 ppm corresponds roughly to a 1-hour standard of about 0.095 to 0.10 ppm. If such a standard were adopted, many areas now classified as moderate or marginal ozone non-attainment areas and therefore not in the RFG program enter the program in the future. Ultimately, RFG could constitute about 30% of the gasoline pool in PADD 2. Additionally, areas now in compliance with ozone standards might be out of compliance with the new standard and could enter the RFG program.

3.0 Factors Affecting the Value of Ethanol

The value of ethanol to the refining sector in PADD 2 in the future will be determined by the interactions of numerous technical, regulatory, and economic factors. Among the major factors that will influence the future demand for ethanol are:

---

[3] About 92% of ethanol use in 1994 in PADD 2 was in 10% gasohol, with the remaining 8% used in 7.7% oxygenated gasoline (1995 Highway Statistics). Many states in the Midwest promote the use of ethanol through various state subsidies, in addition to the federal subsidy.

[4] California's shift to 100% CARB RFG will reduce the use of ethanol in winter oxygenated-gasoline-only areas.

- crude oil and methanol prices;
- growth in RFG usage;
- developments in refining technology;
- the capital stock (process capacity) of the refining sector;
- infrastructure requirements to accommodate ethanol blended directly into conventional gasoline or RFG; and
- consumer preferences regarding ethanol-blended gasoline.

Ethanol currently has two routes into the gasoline pool: (1) as a feedstock to refinery-based or merchant ether production and (2) as a direct blendstock in conventional gasoline and RFG. When used as an ether feedstock, ethanol competes with methanol. Given that ETBE-blended gasoline produced at the refinery is pipeline-compatible and fungible with MTBE-blended gasoline, the *market value* of ethanol as an *ether feedstock* is its *refining value.* The *refining value* of ethanol is determined by its value as an ether feedstock or by the refining values of the gasoline blendstocks it displaces.

The market value of ethanol used as a *direct gasoline blendstock*, however, typically is less than its refining value, because ethanol blending incurs extra costs downstream of a refinery. Ethanol-blended gasoline is not pipeline-compatible, so in most situations ethanol is blended into finished gasoline at bulk terminals or other splash-blending sites. In addition, consumers may value ethanol-blended gasoline (at comparable octane) lower than conventional gasoline, because of reduced mileage.[5] Hence, the *market value* of ethanol as a *direct blendstock* is its *rack value* (its value at a bulk terminal or other splash-blending site). This would reflect its refining value, adjusted for the costs associated with ethanol's use that are incurred downstream of the refinery and for any consumer preference effect on the market price of the finished gasoline.

If, in the future, ethanol were no longer to benefit from the 1 psi RVP waiver (as we assume in this analysis) and much larger volumes of ethanol were blended into gasoline, ethanol blenders would incur distribution costs not now incurred. In particular, "sub-grade" gasoline blends destined for ethanol blending would have to be segregated from conventional gasoline, not only because their RVP would have to be 1 psi lower than the summer RVP standard, but also to enable marketing of the full complement of gasoline grades, while still taking advantage of ethanol's high octane.

The same would be true for RFG -- EPA regulations require that reformulated blendstocks for oxygenate blending (RBOBs) be segregated from ether-blended RFG. The necessity of

[5] Ethanol's fuel economy deficit in *conventional gasoline* amounts to about a 0.8% mileage loss for each 1.0% oxygen content in the gasoline. It arises from ethanol's low energy density -- about 2/3 that of conventional gasoline. The mileage loss associated with ethanol-blended conventional gasoline is a significant social cost associated with using ethanol and, if fully recognized by consumers, would significantly reduce the value of ethanol to refiners/blenders. However, the fuel economy deficit for *RFG* is similar for ether-blended RFG or ethanol-blended RFG, so there is no *relative* fuel economy penalty for directly blending ethanol in RFG.

segregating these gasolines in the product distribution system would increase the logistics costs associated with using ethanol at the margin and reduce its rack value. Ethanol's market price would have to be low enough to offset the added distribution (infrastructure and additional handling) costs in order to induce refiners to switch from producing refinery-blended finished RFG and conventional gasoline to gasoline blends formulated so that they meet conventional and RFG specifications when blended with ethanol at bulk terminals.[6]

The "demand functions" estimated in this analysis apply to ethanol's *refining value*. Consequently, they tend to overstate the market value of ethanol.

4.0 Seasonal Use of Ethanol

In PADD 2, most fuel ethanol is blended into conventional gasoline on a year-round basis. Some ethanol is used to manufacture ETBE, and some is blended in RFG in both the summer and winter seasons. Use of ethanol as the oxygenate in summer RFG is facilitated by the location of RFG-producing refineries close to the Milwaukee-Chicago market area and by the current RVP requirement for summer, Class C RFG of 8.1psi. The former enables refiners to segregate RBOB (refinery blendstocks for oxygenate blending) from other finished gasolines; the latter sets a technically feasible RVP limit for RBOB destined for ethanol blending of about 7 psi. However, the RVP of Phase 2 summer RFG will be in the range of 6.5 to about 7.0 psi. Phase 2 RBOB destined for ethanol blending therefore must have an RVP of 5.5 to 6.0 psi, which is either not technically feasible or prohibitively expensive to meet. Hence, direct blending of ethanol in summer RFG during the time period examined in this study is unlikely to be practiced.

We assume in this analysis that the use of ETBE in RFG and ethanol in conventional gasoline is constant across seasons and that the stock of refining process capacity is optimized for constant use across seasons. As discussed in the 18 July study, seasonal switching of ethanol in RFG (from direct blendstock in the winter to ether feedstock in the summer) would entail significant costs because of its effects on: (1) utilization of oxygenate production capacity; (2) the value of ether feedstocks; and (3) operating costs of retail outlets.

5.0 Methodology and Scenarios

We employed our generalized refinery modeling system (ARMS) to assess the PADD 2 refining sector's demand for ethanol. The ARMS runs performed in this analysis simulate (1) ethanol producers placing specified volumes of ethanol on the market at market-clearing prices and (2) refiners making optimal use of resources (including ethanol), capital stock, and new technologies available to them. Consequently, the results of the analysis represent "market-driven" (as opposed to "mandated") ethanol use for each scenario assessed.

---

[6] These additional distribution costs would be incurred during a transition period in which ethanol-blended gasoline displaced progressively larger volumes of conventional gasoline.

The scenarios examined in this analysis are as follows. (They are same as in the 18 July study, except that only one scenario for refining capacity is examined.)

- Crude Oil and Natural Gas Prices. Long-term oil (and natural gas) prices are the most important single determinant of ethanol's refining value. To capture the effects of oil and gas price levels on ethanol's refining value, we developed demand functions for fuel ethanol at three forecast levels of crude oil and natural gas prices, shown in Table A.

Table A: AEO Price Forecasts for Crude Oil and Natural Gas: 2010

World Oil Price Projection	Crude Oil (1993 $/Bbl)	Natural Gas (1993 $/MCF)
• **Low**	$14.69	$2.88
• **Mid-range**	$24.12	$3.39
• **High**	$28.99	$3.51

The three sets of forecasts are for the year 2010 and for the reference economic growth rate in the *1995 Annual Energy Outlook* (AEO), published by the Energy Information Administration of the U.S. Department of Energy. To the extent that these prices represent a range within which crude oil (and natural gas) prices are likely to fall over the next fifteen years, our analysis is likely to capture the magnitude of the effects of crude oil prices on ethanol values.

- Refining Process Capacity. We allowed ARMS to optimize PADD 2's refining process capacity to produce 30% RFG without using ethanol (either as a feedstock for ethers or as a direct gasoline blendstock) and 70% conventional gasoline (using 70,000 bbl/d of ethanol as a direct blendstock). We used this optimized process capacity as the "existing" capacity in the year 2010 for subsequent ARMS runs. This simulates a situation in which (1) increases in the use of ethanol (beyond the current levels) occur after expansion of RFG areas and (2) refiners evaluate ethanol with process capacity already in place to produce requisite volumes of conventional gasoline and ether-blended RFG.

- Pattern and Volume of Ethanol Use. The pattern of ethanol use for any given volume of ethanol is determined by its highest-valued use at the margin. This pattern varies across scenarios and is strongly influenced by the relationship between crude oil and methanol prices. Ethanol's value is highest as an ether feedstock when methanol prices are high and crude oil prices are low; ethanol's value is highest as a direct gasoline blendstock when crude oil prices are high. Thus, ethanol's path into the gasoline pool, determined by its marginal value as an ether feedstock and as a direct gasoline blendstock, will depend on future crude oil prices, methanol prices, and other factors, such as logistics costs. In our analyses, ethanol's path into the gasoline pool is determined by the marginal use with the highest refining value.

For each crude oil and natural gas price forecast, we estimated ethanol's refining value at three or more levels of ethanol use in the PADD 2 gasoline pool, ranging from 10 M bbl/d to about 150 M bbl/d. The former value corresponds roughly to the current level of use in PADD 2; the latter corresponds to ethanol's use in most conventional gasoline and RFG produced by PADD 2 refineries.

- Displacement of Inter-PADD Shipments of Gasoline. Increased use of ethanol by PADD 2 refineries is likely to reduce the volume of net gasoline shipments from adjacent PADDs, primarily PADD 3. In this analysis, we assumed that net gasoline shipments into PADD 2 would decline by the additional volume of ethanol blended into the gasoline pool (as ethanol or ETBE). This assumption tends to slow the decrease in refining value of ethanol with increasing ethanol volume relative to the values estimated in the previous study.

6.0 Model Inputs -- Boundary Conditions

The data used to set the boundary conditions for the various ARMS runs (crude oil and other refinery inputs, product outputs, and refining capacity) are shown in Exhibits 6 through 10.

- Exhibit 6 shows the prices for key refinery inputs and refined outputs for each AEO price scenario. Prices for propane, methanol, and MTBE are the same as in the 18 July study. We increased the prices of butane and iso-butane by $1.25/bbl to be consistent with the valuations of baseline input volumes in ARMS.

- Exhibit 7 provides a breakdown of the crude oil slate for each price scenario. In each model run, Saudi Arabian Light is the "swing crude," i.e., the crude oil whose volume is allowed to vary and whose price corresponds to an AEO world oil price projection.

- Exhibit 8 shows the volume of purchased fuel and unfinished oil inputs. We left butane inputs open (volume optimized at the given price) -- future RVP reductions for summer, Phase 2 RFG and greater ethanol use in conventional gasoline should eliminate the use of butane on a net annual basis. We set a minimum for iso-butane use of 36 M bbl/d, based on current use, and allowed up to 10 M bbl/d of additional purchases at a higher price (25 ¢/bbl more than shown in Exhbit 6). This simulates a price effect of additional demand for iso-butane and also keeps the volumes purchased consistent with projected percentage increases in the U.S. production of natural gas liquids. Only in the low oil price scenario is more iso-butane purchased for use as alkylation feed.

- Exhibit 9 shows projected PADD 2 refinery outputs for each crude oil price scenario for the year 2010. The projections were made by adjusting current PADD 2 refinery output for the growth in each product category projected by the AEO for the entire U.S. We fixed the product slate in all ARMS runs at projected refinery output volumes, with several exceptions: (1) refinery gasoline production was increased to reflect increased use of ethanol; (2) propane and butane production was unconstrained in all ARMS runs, i.e., they were produced at volumes such that their marginal refining costs equaled their prices; (3) residual oil production was unconstrained, with low sulfur residual oil prices set at 92% of crude oil prices and high sulfur residual oil prices set at 78% of crude oil prices. (The latter price ratios are based on the observed relationship between the price of Saudi Light delivered to the Gulf Coast and spot residual oil prices over the two year period 1993 - 1994.) At these prices, the computed output of residual oil is less than the projected output, primarily because the ARMS runs allow addition of new coking conversion capacity that uses residual oil feeds.

- Exhibit 10 shows current process capacities and baseline process capacities for the year 2010 for the mid-range price scenario. Baseline process capacities for 2010 reflect the results of ARMS runs in which process capacity is optimized (given a starting base capacity 30% lower than in 1995, except for oxygenate capacity) to produce 30% RFG.

7.0 Other Assumptions in ARMS Runs

Other assumptions incorporated in our analysis include:

- The PADD 2 refining sector can be considered as one aggregate refinery for purposes of estimating ethanol's refining values.

- Refiners in PADD 2 would not tailor refining capital stock to accommodate increased volumes of ethanol in advance of their commercial availability.

- The long-term price of methanol is a function of the natural gas price and includes a suitable return on invested capital.

- No public policies are in place in 2010 to promote ethanol use. Specifically, we assume no ethanol tax subsidy and no 1 psi RVP waiver for ethanol blending in conventional gasoline.

- Maximum oxygen content is 2.7 wt% for ether-blended RFG, 3.5 wt% for ethanol-blended conventional gasoline, and 2.7 wt% in the summer and 3.5 wt% in the winter (an annual average of 3.1 wt%) for ethanol-blended RFG.

- RFG must satisfy emission standards for federal Phase 2 RFG. (The required gasoline specifications are based on previous analyses conducted by MathPro Inc. regarding EPA's Phase 1 and Phase 2 RFG standards.) RVP specifications for Phase 2 RFG and conventional gasoline are set as the average of the requirements for summer and winter

RVPs (assuming 100% Class C gasoline). Other conventional gasoline properties are set at baseline levels to simulate the anti-dumping requirements.

- Distillate and resid specifications satisfy existing EPA standards and industry specifications.
- The gasoline grade split is: 15% premium, 10% mid-grade, and 75% regular. (Octane demand in PADD 2 is less than in other parts of the U.S.)
- No MMT is blended in gasoline, though it is now allowed, up to 1/32 g/gal, in conventional gasoline.

8.0 Results of ARMS Runs

This section describes the primary results of our analysis. We assume, in all scenarios assessed, that the PADD 2 refining sector optimizes its capital stock to produce required RFG and conventional gasoline volumes before additional volumes of ethanol are introduced to the market.

2010 Baseline Oxygenate Capacity and Purchases

The PADD 2 refining sector could produce the required volume of RFG at least cost through various combinations of investment in internal ether capacity, purchases of merchant MTBE, and investment in alkylation capacity. Based on the assumptions made for key refinery inputs and our estimates of refining process economics, ARMS indicates that the PADD 2 refining sector would fill most of its oxygenate requirements by investing in internal MTBE capacity (about 30 M bbl/d of new capacity in addition to 12 M bbl/d of existing capacity) and DIPE capacity (about 60 M bbl/d). Residual oxygenate needs would be satisfied by purchasing merchant MTBE (about 20 M bbl/d).[7]

Other, higher cost, routes to meeting oxygenate requirements include purchases of more merchant MTBE, investment in more internal MTBE capacity, and investment in more alkylation capacity. We explored these means of meeting RFG requirements in developing the projections of baseline refining capacity for 2010, but we used the low-cost route indicated above in our analyses of the refining value of ethanol. This projection of baseline capacity is consistent with the projections of baseline capacity made in previous reports.

If MTBE prices were about 10% lower than projected (or about 95 ¢/gal for the mid-range price scenario), most of the increase in oxygenate requirements would be satisfied by

[7] In this scenario, a small volume of MTBE is blended in conventional gasoline as a means of meeting the anti-dumping requirements -- about 2% by volume.

purchases of merchant MTBE. (In the ARMS runs embodying this price assumption, investment in internal MTBE capacity was only about 20 M bbl/d and investment in DIPE capacity was zero.) However, low MTBE prices also would discourage investment in merchant MTBE capacity in the U.S., implying that the added MTBE purchases would be imports. Methanol feed for this volume of MTBE production could not be replaced by ethanol (because the MTBE production capacity would be located outside the U.S.); similarly, DIPE capacity could not be converted to ethanol-based ethers. Hence, the implications for ethanol demand are similar for the scenario in which there is significant investment in DIPE capacity and the scenario in which most of the increased oxygenate requirements are met by importing MTBE.

Refining Value of Ethanol

The primary results of our analyses are shown in Exhibit 11. The exhibit delineates the relationships between the *refining value* of ethanol and the volume of ethanol used by refineries, either as an ether feedstock or as a direct gasoline blendstock, for each price scenario and for specified assumptions regarding refinery capacity and other factors.[8] Though we term these relationships "demand functions" to simplify our exposition, they overstate the true demand functions for ethanol, because the *market price* for ethanol used as a direct blendstock in conventional gasoline is lower than its *refining value*, for reasons discussed earlier.

- PADD 2 refineries could use up to about 150 M bbl/d of ethanol. After that, its refining value would decline substantially.

- In the high and mid price scenarios, ethanol enters the gasoline pool first as a direct blendstock in conventional gasoline (up to about 140 M bbl/d) and then as an ether feedstock. In the low price scenario, the order is reversed -- ethanol enters the gasoline pool first as an ether feedstock (about 10 to 15 M bbl/d) and then as a direct blendstock in conventional gasoline.

- The value of ethanol declines with volume, though not as significantly as indicated in previous reports, primarily because we increased gasoline output by the additional volume of ethanol introduced into the gasoline pool.

- The price of crude oil is the major determinant of the value of ethanol blended into conventional gasoline. The price of methanol is the major determinant of the value of ethanol used as a feedstock to in the production of ETBE.

[8] For each price/ethanol use scenario shown, we increased refinery output of conventional gasoline by the volume of ethanol use above the baseline level (about 40 M bbl/d of corn-based ethanol). This simulates a barrel-for-barrel reduction in net shipments of gasoline into PADD 2. If, instead, we had fixed the volume of gasoline output by PADD 2 refiners across all scenarios, the marginal cost of producing gasoline would be lower and the value of ethanol would be lower than shown in Exhibit 11.

In previous studies of the U.S refining sector, RFG was projected to comprise 50% of gasoline production, whereas in this study of the PADD 2 refining sector it was projected to comprise 30% of gasoline production. If RFG's share of the PADD 2 refining sector's gasoline production were 50%, the "demand curves" shown in Exhibit 11would stay at the same levels. However, the "break points" on the curves and the maximum volume of ethanol use would change. For example, the "break point" for the curves representing demands for the high and mid price scenarios would shift to about 100 M bbl/d and the maximum volume of ethanol use could decline by up to 40 M bbl/d, depending on the marginal source of additional ethers for RFG. The "break point" for the curve representing demands for the low price scenario would shift outwards to as much as about 35 M bbl/d and the maximum volume of ethanol use could decline by as much as 40 M bbl/d, again depending on the marginal source of ethers for RFG.

The results of this PADD 2 analysis are consistent with those of previous studies of the entire U.S refining sector. In particular, the effects of changes in various assumptions on the "demand curves" for ethanol estimated in the previous studies (e.g., refining capacity optimized for ethanol availability and retention of the 1 psi RVP waiver) would apply to the PADD 2 "demand curves" estimated in this study.

References

Energy Information Administration, *Annual Energy Outlook, 1995, with Projections to 2010*, January 1995.

Energy Information Administration, *Petroleum Marketing Monthly*, 1995 issues.

Energy Information Administration, *Petroleum Supply Annual, 1993*, June 1994.

Energy Information Administration, *Petroleum Supply Annual, 1993*, May 1995.

Energy Information Administration, *Petroleum Supply Monthly*, 1995 issues.

Information Resources, Inc., *Transportation Fuel Reformulation: 1995 - 2005*, November 1994.

MathPro, Inc., "Effects of the 1 psi RVP Waiver on the Refining Value of Ethanol as Gasoline Blendstock and Etherification Feedstock," submitted to National Renewable Energy Laboratory, November 14, 1995.

MathPro, Inc., "The Refining Value of Ethanol as Gasoline Blendstock and Etherification Feedstock," submitted to National Renewable Energy Laboratory, July, 18, 1995.

Williamson, Michelle, Ed., "Worldwide Refining Survey," *Oil & Gas Journal*, Dec. 18, 1995.

Exhibit 1

Composition of Petroleum Administration for Defense Districts

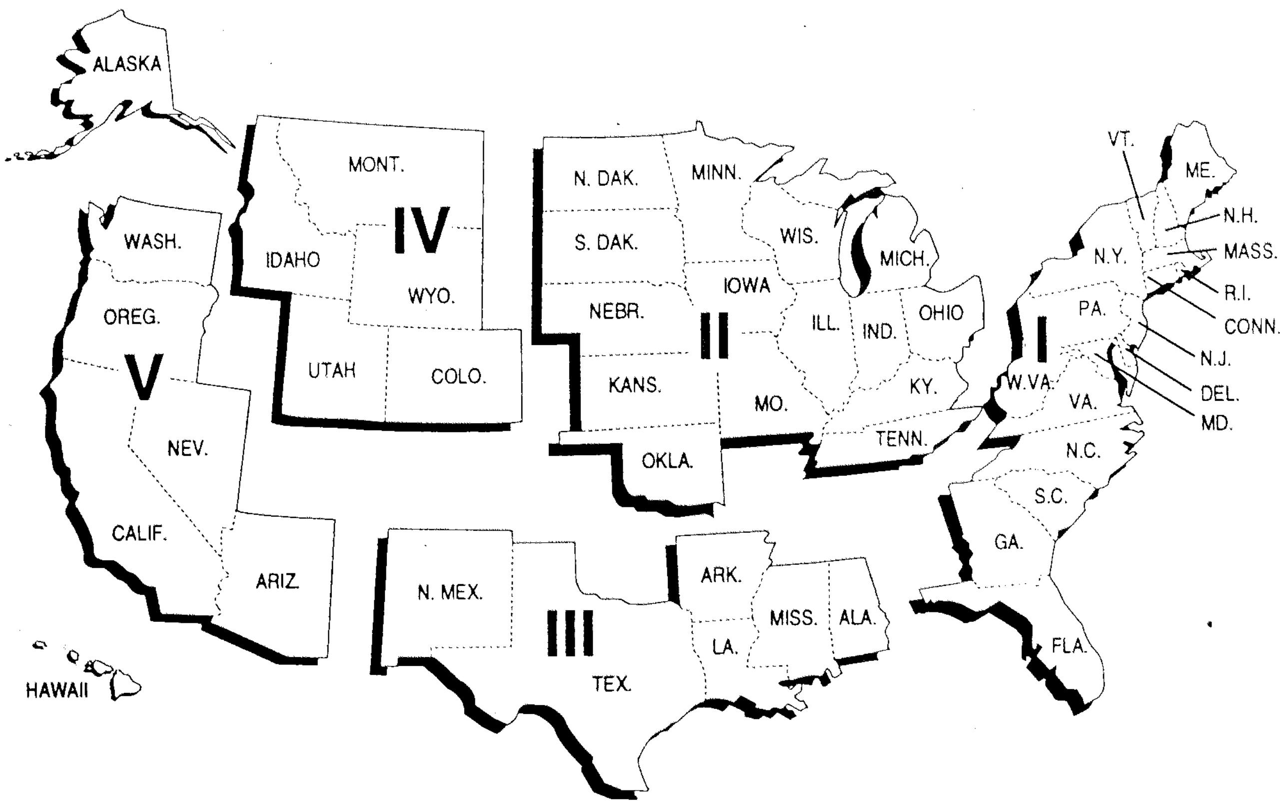


Exhibit 2

PADD 2 Refining Capacity -- 1995

(barrels per stream day)

			Thermal Cracking					Cat. Reforming		Cat.	Catalytic Hydrotreating				Other Processes									Miscellaneous				
	Crude	Vacuum	Delayed	Fluid		Other/	Cat			Hydro	Heavy	Naphtha		Other/	Solv.	Alky-		Isomers		Cat.	Dimer-	Oxygenates			H2		Sulfur	
Location/Refinery	Dist.	Dist.	Coking	Coking	Visb.	Gas Oil	Crack	Low	High	Crack.	Gas Oil	Feeds	Dist.	Resid.	Deasph.	lates	Arom.	Butane	Pen./Hex.	Polm.	sol	MTBE	TAME	Lubes	MMcf/d	Coke	ST/d	Asphalt
NOIS																												
Oil & Refining Corp - Blue Island	85,000	35,950					30,000	18,000	11,000	9,000		21,000				5,000		1,000	3,000						25		22	10,000
Oil & Refining - Hartford	64,000	30,000	15,500				29,000		15,000			20,000	14,700			8,500			3,750						3	4,800	110	2,500
Refining - Lawrenceville	85,000	23,000					30,000		15,000			15,000	20,000			6,000											70	4,500
hon Petroleum Co. - Robinson	180,000	50,000	24,600			5,000	43,000	76,000		24,000	24,000	60,000	60,000	14,000		12,500	0		4,900			1,700				7,250	180	
Oil Corp. - Joliet	196,000	92,500	44,000				98,000		43,900			81,000	68,000			25,000										11,750	395	
Oil Co. - Wood River	291,000	107,000					92,000	75,000	16,000	33,500	29,000	61,500	75,000	10,500		22,000	4,500							7,600	57		450	45,000
ven Co. - Lemont (Chicago)	153,000	62,000	27,500				65,000		29,800		4,300	46,700	44,000			18,000	3,500								11	1,714	390	
Total	1,054,000	400,450	111,600	0	0	5,000	387,000	169,000	130,700	66,500	57,300	305,200	281,700	24,500	0	97,000	8,000	1,000	11,650	0	0	1,700	0	7,600	96	25,514	1,617	62,000
ANA																												
co Oil Co. - Whiting	425,000	240,000	30,000				157,000		90,000		98,300	115,000	90,000			32,000	15,000		22,000			3,600		6,000	35	11,300	410	60,000
try Mark - Mt. Vernon	24,000	7,200					8,000	6,500				10,000				1,700			2,200									2,200
on Refining Co. - Laketon	2,500	0														5,650												3,800
Total	451,500	247,200	30,000	0	0	0	165,000	6,500	90,000	0	98,300	125,000	90,000	0	0	33,700	15,000	0	24,200	0	0	3,600	0	6,000	35	11,300	410	66,000
SAS																												
land Industries, Inc. - Coffeyville	70,000	28,000	15,000				25,000		16,000			26,500	30,000			6,000			8,500							5,040	39	
nal Co-op Refinery - McPherson	80,000	27,000	22,000				22,800		20,000			31,500	30,500			6,000		2,000	9,500							3,323	66	
co Refining & Marketing - El Dorado	95,700	36,000	15,400				31,500		25,700		44,000	40,500	27,500			12,000	2,500		15,000							3,750	279	
Petroleum, Inc. - Arkansas City	60,000	16,150					19,500	12,000	6,000	3,190		18,000				5,500											20	2,500
Total	305,700	107,150	52,400	0	0	0	98,800	12,000	67,700	3,190	44,000	116,500	88,000	0	0	29,500	2,500	2,000	33,000	0	0	0	0	0	0	12,113	404	2,500
TUCKY																												
and Oil, Inc. - Catlettsburg	220,000	92,000			4,500	55,000	100,000	43,500			40,000	74,500	80,000	22,000	10,000	12,000	6,000	4,000	12,000	1,000		3,200		8,500	20		400	30,000
erset Refinery, Inc. - Somerset	6,300								1,000			1,300							250									
Total	226,300	92,000	0	0	4,500	55,000	100,000	43,500	1,000	0	40,000	75,800	80,000	22,000	10,000	12,000	6,000	4,000	12,250	1,000	0	3,200	0	8,500	20	0	400	30,000
HIGAN																												
thon Petroleum Co. - Detroit	72,000	38,000					27,500	15,000			11,200	17,000	21,800			4,200						1,141					120	28,000
Petroleum, Inc. - Alma	51,000						19,500	15,000			3,800	23,000	19,500	2,000		6,200			3,500		900						58	
Total	123,000	38,000	0	0	0	0	47,000	30,000	0	0	15,000	40,000	41,300	2,000	0	10,400	0	0	3,500	0	900	1,141	0	0	0	0	178	28,000
NESOTA																												
and Oil, Inc. - St. Paul	69,220	32,000					23,000		23,500		23,000	32,800	20,000			5,500			8,300	400						10,000	100	14,000
n Refining Co. - St. Paul (Pine Bend)	240,000	160,000	68,000				76,000	36,000	15,000		89,000	81,000	80,000			12,000			15,000	1,100	3,700	1,500			80	18,000	750	25,000
Total	309,220	192,000	68,000	0	0	0	99,000	36,000	38,500	0	112,000	113,800	100,000	0	0	17,500	0	0	23,300	1,500	3,700	1,500	0	0	80	28,000	850	39,000
RTH DAKOTA																												
oco Oil Co. - Mandan	60,000						26,000		12,100			19,100				4,800			5,100	1,100							17	
Total	60,000	0	0	0	0	0	26,000	0	12,100	0	0	19,100	0	0	0	4,800	0	0	5,100	1,100	0	0	0	0	0	0	17	0
O																												
and Oil, Inc. - Canton	68,000	33,000					25,000	20,000			23,000	26,500	7,000			7,000			6,500	1,000							110	12,000
Oil Corp. - Lima	165,000	52,000	21,500				36,000		55,000	23,500		60,000					7,000	4,500	17,500						29	3,750	40	2,000
Oil Corp. - Toledo	140,000	52,000	19,000				35,000		42,000	26,000		40,000				11,000									24	4,046	100	12,000
Co., Inc. - Toledo	128,000	30,000					60,000		45,600	28,000		40,000			9,000	7,800	9,000			2,800				200	48		45	2,500
-Total	501,000	167,000	40,500	0	0	0	176,000	20,000	142,600	77,500	23,000	166,500	7,000	0	9,000	25,800	16,000	4,500	24,000	3,800	0	0	0	200	101	7,796	295	28,500
LAHOMA																												
ett Refining Corp. - Thomas (Custer)	11,200																											
oco, Inc. - Ponca City	145,000	45,000	21,500				53,000		40,000		18,000	40,000	40,000			13,000		6,000	10,000	2,100		1,000				4,800	94	
-McGee Refining Corp. - Wynnewood	45,000	14,000					18,000	12,500	0	5,000		11,000			4,400	5,000			4,000						10			5,000
lair Oil Corp. - Tulsa	59,000	27,000					19,000		12,000			20,000	17,500			3,600			4,300								20	7,300
Co., Inc. - Tulsa	90,000	29,000	8,000				35,000		25,000			25,000		10,000	5,800	7,000	2,200	3,000						7,500		1,500		4,600
l Petroleum, Inc. - Ardmore	70,000	32,000					26,000	17,000			28,000	24,000	28,000	0		7,000			1,100						26		128	6,000
-Total	420,200	147,000	29,500	0	0	0	151,000	29,500	77,000	5,000	46,000	120,000	85,500	10,000	10,200	35,600	2,200	9,000	19,400	2,100	0	1,000	0	7,500	36	6,300	242	22,900
NNESSEE																												
oco Petroleum, Inc. - Memphis	91,000	12,000					42,000	15,000				18,000	34,000			3,200			3,300	3,000							50	3,500
-Total	91,000	12,000	0	0	0	0	42,000	15,000	0	0	0	18,000	34,000	0	0	3,200	0	0	3,300	3,000	0	0	0	0	0	0	50	3,500
SCONSIN																												
rphy Oil USA, Inc. - Superior	35,000	20,500					11,000	8,000				9,000	5,800			1,600			2,000								14	13,500
-Total	35,000	20,500	0	0	0	0	11,000	8,000	0	0	0	9,000	5,800	0	0	1,600	0	0	2,000	0	0	0	0	0	0	0	14	13,500
tal:	3,576,920	1,423,300	332,000	0	4,500	60,000	1,302,800	369,500	559,600	152,190	435,600	1,108,900	813,300	58,500	29,200	271,100	49,700	20,500	161,700	12,500	4,600	12,141	0	29,800	368	91,023	4,477	295,900

Exhibit 3: Crude Oil Use by PADD 2 Refineries, 1994

Source	Volume		Sulfur	Gravity	
	M bbl	M bbl/d	(wt%)	API	Specific
DOMESTIC:	**703,643**	**1,928**	**0.81**	**36.6**	**0.842**
FOREIGN:	**450,614**	**1,235**	**1.56**	**30.7**	**0.872**
ANGOLA	9,494	26	0.21	32.7	0.862
ARGENTINA	448	1	0.48	34.8	0.851
AUSTRALIA	401	1	0.03	53.9	0.763
CANADA	250,352	686	1.73	30.1	0.876
COLOMBIA	6,576	18	0.56	29.1	0.881
CONGO	1,365	4	0.28	27.4	0.890
ECUADOR	6,307	17	0.73	28.8	0.883
GABON	461	1	0.06	33.9	0.856
INDONESIA	1,228	3	0.31	43.4	0.809
KUWAIT	17,102	47	2.61	31.1	0.870
MEXICO	29,585	81	2.37	26.9	0.893
NIGERIA	15,895	44	0.17	36.5	0.842
NORWAY	2,713	7	0.28	33.2	0.859
RUSSIA	1,915	5	1.37	32.7	0.862
SAUDI ARABIA	31,250	86	1.74	33.3	0.859
THAILAND	455	1	0.10	56.0	0.755
TRINIDAD & TOBAGO	540	1	0.30	32.8	0.861
UNITED KINGDOM	22,206	61	0.46	37.8	0.836
VENEZUELA	49,938	137	1.38	28.5	0.885
YEMEN	2,383	7	0.36	36.5	0.842
TOTAL:	**1,154,257**	**3,162**	**1.11**	**34.3**	**0.854**

Sources:
Derived from Detailed DOE Crude Oil Import Data, 1994; and
Petroleum Supply Annual, 1994, Table 16.

Exhibit 4

Fuel Ethanol Production Capacity, by PADD -- 1995

(barrels per day)

PADD/ State	Company	City	Capacity Operating	Capacity Idle
PADD 1			**326**	**326**
Florida	Bartow Ethanol Inc.	Clearwater		326
Virginia	Butterwood Farms	Wilsons	326 e	
PADD 2			**106,237**	**6,743**
Illinios	Archer Daniels Midland Co.	Decatur	19,677 e	
	Archer Daniels Midland Co.	Peoria	12,650 e	
	Midwest Grain Products Inc.	Pekin	4,700	
	Willions Energy Ventures	Pekin	6,523	
	Vienna Agricultural Research Center	Vienna	33	
Indiana	New Energy Co. of Indiana	South Bend	5,810	
Iowa	Archer Daniels Midland Co.	Cedar Rapids	10,541 e	
	Archer Daniels Midland Co.	Clinton	6,325 e	
	Cargill Inc.	Eddyville	1,860	
	Grain Processing Corp.	Muscatine	1,566	
	Manildra Energy Corp.	Hamburg	405	
	Permeate Refining Co.	Hopkinton	131	
	Roquette America Inc.	Keokuk	1,425	
Kansas	Ese Alcohol Inc.	Leoti	85	
	High Plains Corp.	Colwich	1,500	
	Midwest Grain Products Inc.	Atchinson	397	
	Reeve Agri Energy	Garden City	714	
Minnesota	Corn Plus	Winnebago	1,000	
	G & S Gasahol Inc.	Mankato		107
	Heartland Corn Products	Winthrop	652	
	Kraft General Foods	Melrose	125	
	Milwaukee Slovents & Chem. Corp	Morris	400	
	Minnesota Clean Fuels	Dundas	85	
	Minnesota Corn Processors	Marshall	2,381	
	Minnesota Energy	Buffalo Lake	457	
	Planned -- 1996		3,262	
North Dakota	Alcem Ltd.	Grafton	686	
	Archer Daniels Midland Co.	Walhalla		1,826
Nebraska	Ag Processing Inc.	Hastings	1,957	
	Cargill Inc.	Blair	4,566	
	Chief Ethanol Fuels Inc.	Hastings	1,826	
	High Plains Corp.	York	2,000	
	Minnesota Corn Processors	Columbus	5,900	
	Nebraska Energy	Aurora	1,631	
	Planned -- 1995		978	
Ohio	South Point Ethanol	South Point		4,810
South Dakota	Broin enterprises Inc.	Scotland	476	
	Heartland Ethanol	Aberdeen	417	
Tennesse	A.E. Staley Manf.	Loudon	3,095	
PADD 3			**0**	**1,205**
New Mexico	Giant Refining Co.	Portales		985
	Grain Power of New Mexico	Tucumcari		220
PADD 4			**938**	**0**
Colorado	AG Power of Colorado	Golden	100	
Idaho	J. R. Simplot Co.	Caldwell	270	
	J. R. Simplot Co.	Heyburn	230	
Montana	Alcotech Inc.	RIngling	142	
Wyoming	Wyoming Ethanol	Torrington	196	
PADD 5			**828**	**0**
California	Golden Cheese Co. of California	Corona	180	
	Parallel Products Inc.	Cucamonga	250	
Washington	Geargia Pacific Corp.	Bellingham	333	
	Pabst Brewing Co.	Olympia	65	
Total U.S.			**108,329**	**8,274**

e -- estimate based on aggregate reported capacity.

Sources: EIA, Petroleum Supply Annual 1994, Table 51 Oxy-Fuel News, Dec. 25, 1995.

Exhibit 5: Ozone Nonattainment Areas in PADD 2

(sorted by classification & alphabetically)

Areas	Design Value (ppm)	Avg. Exp. Exc.	Yr	Class-ification	Number of Counties in Non-Attainment: Before Nov 90	New	Total	Pop. 1990 (1000)	EPA Region		State	CMSA or MSA	Year of SIP Call
Chicago-Gary-Lake County, IL-IN	0.190	13.0	89	Severe-17	6	4	10	7,886	5		IL-IN	cmsa	88
Milwaukee-Racine, WI	0.183	9.8	89	Severe-17	5	1	6	1,735	5		WI	cmsa	88
Cincinnati-Hamilton, OH-KY	0.157	5.4	89	Moderate	7	0	7	1,705	5	4	OH-KY	cmsa	88
Cleveland-Akron-Lorain, OH	0.157	5.2	89	Moderate	7	1	8	2,859	5		OH	cmsa	88
Dayton-Springfield, OH	0.143	3.1	89	Moderate	4	0	4	951	5		OH	msa	89
Detroit-Ann Arbor, MI	0.144	3.7	89	Moderate	7	0	7	4,591	5		MI	cmsa	88
Grand Rapids, MI	0.143	4.4	89	Moderate	2	0	2	688	5		MI	msa	88
Kewaunee Co, WI	0.147	5.5	89	Moderate	0	1	1	19	5		WI	no	88
Louisville, KY-IN	0.149	1.9	89	Moderate	3	2	5	834	4	5	KY-IN	msa	88
Manitowoc Co, WI	0.167	9.9	89	Moderate*	0	1	1	80	5		WI	no	88
Muskegon, MI	0.181	9.4	89	Moderate	1	0	1	159	5		MI	msa	88
Nashville, TN	0.138	5.6	89	Moderate	5	0	5	881	4		TN	msa	88
Sheboygan, WI	0.176	9.1	89	Moderate	1	0	1	104	5		WI	msa	88
St Louis, MO-IL	0.156	6.2	89	Moderate	8	0	8	2,390	7	5	MO-IL	msa	88
Toledo, OH	0.140	2.7	89	Moderate	1	1	2	575	5		OH	msa	89
Canton, OH	0.135	1.7	89	Marginal	1	0	1	368	5		OH	msa	89
Columbus, OH	0.131	1.4	89	Marginal	0	3	3	1,157	5		OH	msa	89
Door Co, WI	0.126	1.8	90	Marginal RT	0	1	1	26	5		WI	no	no
Edmonson Co, KY	0.140	2.1	89	Marginal* R	0	1	1	10	4		KY	no	89
Evansville, IN	0.124	1.1	89	Marginal	0	1	1	165	5		IN	msa	89
Indianapolis, IN	0.121	1.1	89	Marginal	1	0	1	797	5		IN	msa	88
Jersey Co, IL	0.128	3.1	90	Marginal	0	1	1	21	5		IL	msa	88
Knoxville, TN	0.135	1.8	89	Marginal	0	1	1	336	4		TN	msa	89
Lexington-Fayette, KY	0.126	2.0	89	Marginal	0	2	2	249	4		KY	msa	88
Memphis, TN	0.140	2.0	89	Marginal*	1	0	1	826	4		TN	msa	88
Owensboro, KY	0.137	3.7	89	Marginal	0	2	2	88	4		KY	msa	89
Paducah, KY	0.124	1.1	89	Marginal	0	2	2	28	4		KY	no	89
South Bend-Elkhart, IN	0.121	1.1	89	Marginal	2	0	2	403	5		IN	msa	89
Walworth Co, WI	0.129	2.0	89	Marginal	0	1	1	75	5		WI	no	88
Youngstown-Warren-Sharon, OH-PA	0.134	2.1	89	Marginal	2	1	3	614	5	3	OH-PA	msa	89
Kansas City, MO-KS	0.120	1.2	89	SubMarginal	5	0	5	1,362	7		KS-MO	msa	no
Severe:				2				9,621					
Moderate:				13				15,836					
Marginal:				16				6,525					
Total:				31				31,982					

Source: U.S. Environmental Protection Agency

Exhibit 6

Selected Prices for Refinery Inputs and Outputs, by DOE Price Scenario for 2010

Prices (1993 $/Bbl)	DOE Price Scenario			Source
	Mid Price	High Price	Low Price	
World Oil (average refiner acquisition cost)	24.12	28.99	14.65	1
Wellhead Natural Gas (1993 $/mcf)	3.39	3.51	2.88	1
Methanol: full cost	28.35	28.88	26.11	2
variable cost	20.79	21.32	18.55	2
Propane	18.33	22.03	11.13	3
Isobutane	22.96	27.34	14.44	3
Butane	21.75	25.89	13.70	3
U.S. Merchant MTBE: full cost	47.67	54.34	40.92	4
variable cost	34.22	38.60	25.16	4
assumed price	43.53	47.64	35.40	5
Residual Oil: low sulfur	24.60	29.60	14.95	6
high sulfur	20.10	23.20	11.95	6

Sources:

1. Table C-11and C-14, Annual Energy Outlook, 1995, EIA, January 1995
2. Based on natural gas price & near term economics for Gulf Coast developed in Hahn, "Economics of Methanol," Economics Bulletin No. 1, Auto/Oil Research Program, January 1992.
3. Derived based on crude oil prices.
4. Derived based on ARMS data base.
5. 18 July Report to NREL.
6. ARMS baseline model run.

Exhibit 7

Projected Crude Oil Inputs to PADD 2 Refineries, by Type of Crude Oil and DOE Price Scenario for 2010

(M Bbl/day)

Crude Oil	% Sulfur	Gravity		Crude Oil Volume			
					DOE Price Scenario		
		API	Specific	1994	Mid	High	Low
Domestic:							
Composite Domestic Crude	0.82%	36.8	0.841	1,928	1,850	2,080	1,270
Imports:							
Saudi Arabia Light	1.60%	33.1	0.860	86	110	90	150
Composite Foreign Crude	1.53%	29.9	0.877	1,149	1,470	1,240	1,980
Subtotal:	1.53%	30.1	0.876	1,235	1,580	1,330	2,130
Combined:							
Total:				3,163	3,430	3,410	3,400
API Gravity:				34.1	33.6	34.1	32.5
Specific Gravity:				0.855	0.857	0.855	0.863
Sulfur Content:				1.11%	1.16%	1.11%	1.28%

Sources: Derived from Exhibit 5, Table 4 of 18 July Report; and MathPro assay data.

Exhibit 8

Inputs to U.S. Refineries, 1994 (Actual) and 2010 (Projected)
(M Bbl/day)

Inputs	1994	DOE Price Scenarios		
		Mid	High	Low
Purchased Fuel				
Natural Gas (M FOEB/day)	48	48	48	48
Residual Oil	6	6	6	6
Unfinished Oils (M Bbl/day)				
Isobutane	36	46 max	46 max	46 max
Normal Butane	1	open	open	open
Resid/Gas Oils	26	38	38	38
Natural Gasoline	41	41	41	41

Sources: Derived from Table 13, EIA Petroleum Supply Montlhy, Dec. 1995; and Table 47, EIA, Petroleum Supply Annual, 1994.

Exhibit 9

Refinery Product Slate: 1995 (Actual) and 2010 (Projected), by Price Scenario

(M Bbl/day)

Refined Product	1995 Product Slate	Projected 2010 Refinery Product Slate: Mid	High	Low
LPGs:				
Propane	81	80	81	49
Propylene	32	32	32	20
Normal Butane				
Butylene				
Aviation Gasoline	3	0	0	0
Gasoline Blending Components	26	26	26	26
Gasoline	1,758	1,952	1,928	1,923
Jet Fuel (naphtha)				
Jet Fuel (kerosene)	211	255	262	268
Distillate:				
Low Sulfur Diesel Fuel	497	546	531	571
#2 Fuel Oil	261	315	316	331
Petrochemical Feedstocks:				
Aromatics	24	28	27	26
Naphtha	10	11	11	11
Gas Oils	24	28	27	26
Residual Oil:				
.31% sulfur or less	1	1	1	1
.31% to 1% sulfur	11	12	11	6
1% sulfur & greater	47	8	10	7
Road Oil and Asphalt	191	216	216	217
Lubes and waxes	26	29	29	30
Coke	130	80	84	74
Total:	3,333	3,619	3,593	3,587

Sources:

1995 Product Slate: Derived from Table 13, Petroleum Supply Monthly, DOE, December, 1995.

Projections: Derived using Table 4 of MathPro report to NREL, "The Refining Value of Ethanol as Gasoline Blendstock and Etherification Feedstock," July 18, 1995.

Exhibit 10

Current and Projected Process Unit Capacities for PADD 2 Refineries

(M Bbl/stream day)

Process	1995	Projected 2010 Baseline		
		Mid	High	Low
Crude Distillation	3,577	3,600	3,600	3,600
Vacuum Distillation	1,423	1,400	1,400	1,400
Alkylation: C4	271	190	190	223
C5	-			
Aromatics Recovery	50	35	35	35
Benzene Extraction		2	2	2
Butane Isomerization	21	15	15	15
Butene Isomerization	-			
Catalytic Polymerization	13	9	9	9
Coking: Delayed	526	368	368	368
Fluid				
Flexi	60	212	327	171
Debutanization	open	168	157	177
Desulfurization:				
Distillate	813	751	660	652
FCC Feed	436	440	440	440
Naphtha	1,109	893	906	872
Resid	59	41	41	41
Dimersol	35			
Ether Production:				
MTBE/ETBE	12	42	39	42
TAME/TAEE				
DIPE	-	60	48	54
EIPE	-			
Fluid Cat Cracking	1,303	1,149	1,043	1,138
Hydrogen Production	19	25	24	27
Hydrocracking:				
Distillate Feeds	130	180	172	200
Gas Oil Feeds	22	113	169	168
Lube & Wax Production	30	30	30	30
Pen/Hex Isomerization:				
Once Thru	108	76	76	76
Total Recycle	54	38	38	38
Reforming: 150 psi	93	230	251	217
150-350 psi	837	586	586	586
Resid Cat Cracking	-			
Solvent Deasphalting	29			
Sulfur Recovery	5	4	4	4
Visbreaking	5			

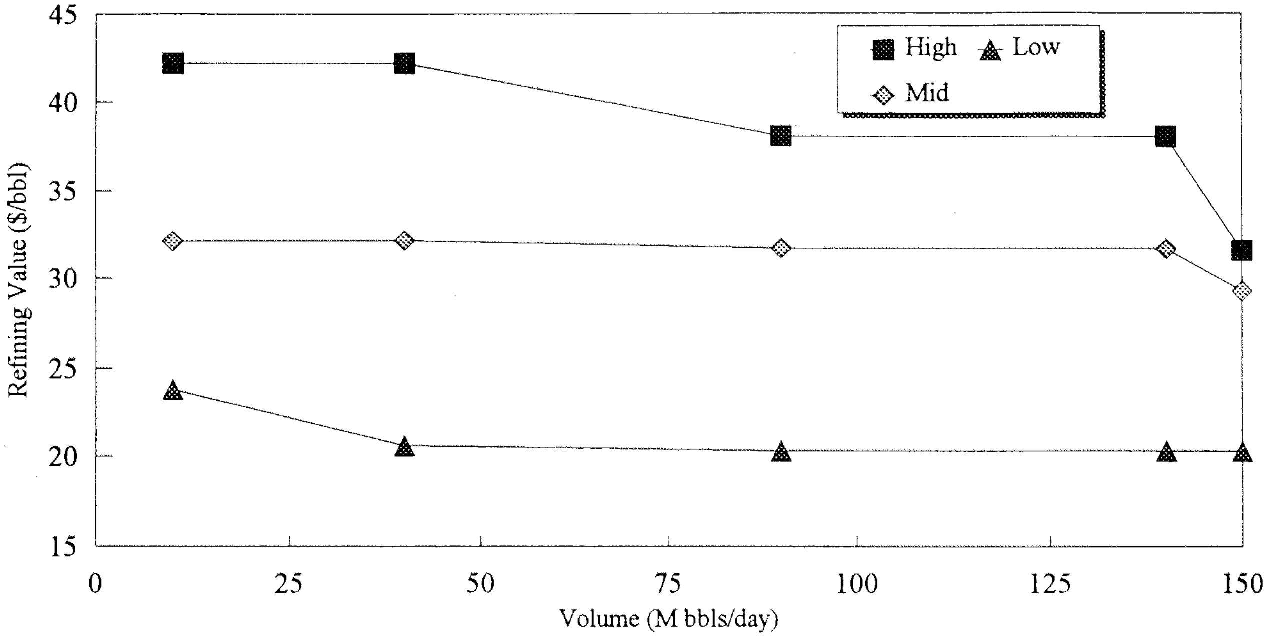
* Base capacity in 2010 equals 1995 capacity less 30% (except for distillation and ether capacity), plus process capacity added by ARMS to optimize production of 30% RFG.

Note: Italics denote commercially available new processes for which little or no new capacity was on-line in 1994

Sources: Exhibit 2 and ARMS runs.

Exhibit 11: Refining Value of Ethanol in PADD 2, by Price Scenario

Capacity Optimized for 30% RFG



Volume of Ethanol (bbl/d)	Oil Price Scenario		
	High	Mid	Low
10	42.20	32.10	23.80
40	42.20	32.10	20.60
90	38.10	31.70	20.30
140	38.10	31.70	20.30
150	31.60	29.30	20.30